

AD-A221 386

MTL TR 90-18

AD

(2)

THE APPLICATION OF NEUTRON RADIOSCOPY TO LITHIUM-ALUMINUM ALLOY TARGET ELEMENTS

JOHN J. ANTAL and ALFRED S. MAROTTA

U.S. ARMY MATERIALS TECHNOLOGY LABORATORY
MATERIALS TESTING AND EVALUATION BRANCH

SALEEM R. SALAYMEH and THOMAS P. VARALLO

E. I. DU PONT DE NEMOURS & CO.
AIKEN, SOUTH CAROLINA

April 1990

Approved for public release; distribution unlimited.

DTIC
ELECTED
MAY 11 1990
S B D



U.S. ARMY MATERIALS TECHNOLOGY LABORATORY
Watertown, Massachusetts 02172-0001

DISCLAIMER

The information contained in this report was developed during work by Westinghouse Savannah River Company under Contract No. DE-A09-76SR00001 with the U.S. Department of Energy and by the U.S. Army Materials Technology Laboratory under Westinghouse Savannah River Company Order No. 0084481.

The findings in this report are not to be construed as an official Department of the Army position, unless so designated by other authorized documents.

Mention of any trade names or manufacturers in this report shall not be construed as advertising nor as an official endorsement or approval of such products or companies by the United States Government.

DISPOSITION INSTRUCTIONS

Destroy this report when it is no longer needed.
Do not return it to the originator.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER MTL TR 90-18	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) THE APPLICATION OF NEUTRON RADIOSCOPY TO LITHIUM-ALUMINUM ALLOY TARGET ELEMENTS		5. TYPE OF REPORT & PERIOD COVERED
7. AUTHOR(s) John J. Antal, Alfred S. Marotta, Saleem R. Salaymeh,* and Thomas P. Varallo*		6. PERFORMING ORG. REPORT NUMBER
9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. Army Materials Technology Laboratory, Watertown, Massachusetts 02172-0001 SLCMT-MRM		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS U.S. Army Laboratory Command 2800 Powder Mill Road Adelphi, Maryland 20783-1145		12. REPORT DATE April 1990
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		13. NUMBER OF PAGES 9
15. SECURITY CLASS. (of this report) Unclassified		
15a. DECLASSIFICATION/DOWNGRADING SCHEDULE		
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited.		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES Published in Proceedings of the 17th Symposium on Nondestructive Evaluation, San Antonio, Texas, April 1989, p. 62-68. *E. I. DuPont De Nemours & Co., Aiken, South Carolina		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Li-Al alloys, Tritium production. (Jes) ✓ Radiography Neutron radiography,		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) (SEE REVERSE SIDE)		

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

Block No. 20

ABSTRACT

We have shown that neutron radioscopy is very useful in locating the position of a Li-Al alloy core enriched in Lithium-6 in tubular aluminum target elements. The alloy core is displaced during a forming process and its location must be redetermined before processing can be completed. The Army's low-flux mobile neutron radioscopy system was employed in these studies as a model system for possible on-line, in-plant use. A series of core end sections of target tubes containing from 0.1 to 4.6 grams of Lithium-6 per foot of length were examined radioscopically with thermal neutrons. The system was able to determine the extent of lithium alloy core from the highest concentrations down to about 0.2 grams of Lithium-6 per foot within one minute of data collection time. A marked loss of sensitivity below this level could be recovered by providing higher geometrical resolution in the images obtained or by using image enhancement techniques. Film radiography was used to verify the accuracy of radioscopic determinations at the lowest lithium concentrations.

7 Present

Accession For	
NTIS GRA&I	<input checked="" type="checkbox"/>
DTIC TAB	<input type="checkbox"/>
Unannounced	<input type="checkbox"/>
Justification	
By _____	
Distribution/	
Availability Codes	
Dist	Avail and/or Special
A'1	2D

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

THE APPLICATION OF NEUTRON RADIOSCOPY
TO LITHIUM-ALUMINUM ALLOY TARGET ELEMENTS

J. J. Antal and A. S. Marotta
Army Materials Technology Laboratory
Watertown, Massachusetts 02172-0001
and
S. R. Salaymeh and T. P. Varallo
E. I. DuPont De Nemours & Co.*
Savannah River Laboratory and Plant
Aiken, South Carolina 29808

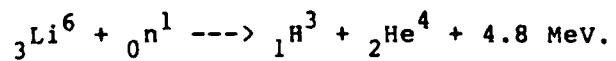
Abstract

We have shown that neutron radioscopy is very useful in locating the position of a Li-Al alloy core enriched in Lithium-6 in tubular aluminum target elements. The alloy core is displaced during a forming process and its location must be redetermined before processing can be completed. The Army's low-flux mobile neutron radioscopy system was employed in these studies as a model system for possible on-line, in-plant use. A series of core end sections of target tubes containing from 0.1 to 4.6 grams of Lithium-6 per foot of length were examined radioscopically with thermal neutrons. The system was able to determine the extent of lithium alloy core from the highest concentrations down to about 0.2 grams of Lithium-6 per ft within one minute of data collection time. A marked loss of sensitivity below this level could be recovered by providing higher geometrical resolution in the images obtained or by using image enhancement techniques. Film radiography was used to verify the accuracy of radioscopic determinations at the lowest lithium concentrations.

INTRODUCTION

The goal of the studies described here was to provide an accurate alternate method for determination of the post-extrusion location of Li-Al alloy core in aluminum target elements to be used in the production of tritium in nuclear reactors. The work is an effort stemming from a mutual interest of the Department of the Army and the Depart-

ment of Energy in diverse applications of the Li-Al alloy system. Lithium-aluminum alloys with lithium content in the 0.8 to 2.5 weight-percent range are used as target material in the production of tritium at Department of Energy facilities. Tritium, H^3 , is produced through the reaction:⁽¹⁾



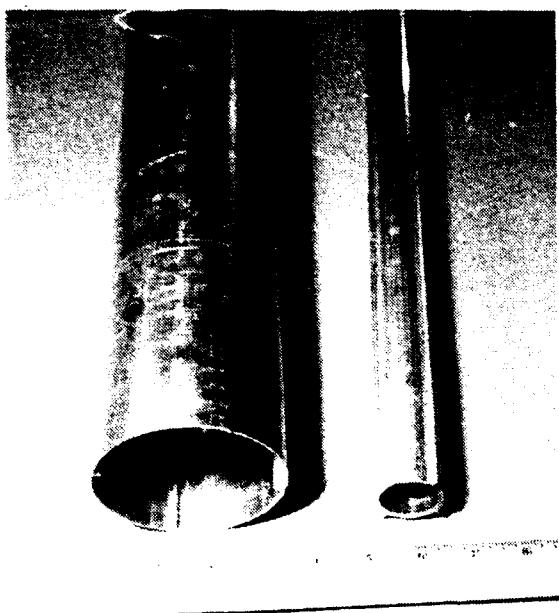


Fig. 1. Photograph of typical target tubes.

The target material, *⁶Li, is in the form of an aluminum-clad Li-Al alloy hollow tube. After a controlled period of irradiation with neutrons in a nuclear reactor, the tube is removed and the tritium generated is recovered from the alloy.

TARGET TUBES

Aluminum tubes approximately 12 feet in length and varying in diameter from about 1.3 inches to 3.6 inches are used as carriers of target material in this application. Figure 1 is a photograph of typical tube sections. The target material may be natural lithium or lithium enriched in the ⁶Li isotope in the form of a lithium-aluminum alloy.* It is common practice to express the lithium content in units of grams of ⁶Li per foot of tube length. The lithium-

aluminum alloy, having essentially the same physical properties as pure aluminum, readily bonds to aluminum in an extrusion cladding operation which results in a uniform metallic tube with the lithium element entirely sealed within aluminum.

Unfortunately, this forming operation displaces the Li-Al alloy in a manner which results in a very nonuniform distribution of the alloy at the two ends of the finished tube. In order to retain all of the target lithium and not defeat the integrity of the cladding seal, it is important to locate the exact extent of the alloy at the core ends. This allows excess aluminum at the core ends to be cut off and disposed of in a later operation.

The present practice is to determine the location of the end of the embedded alloy core with an eddy current probe. An independent nondestructive method for confirming the location of the core end was desired.⁽²⁾ Ultrasonic pulse-echo time of flight measurements were tried, but consistent results could not be obtained at low Li-Al alloy concentrations. The method explored and described here is to provide a neutron radiologic image of a 10-inch section of the core end which maps out the distribution of the alloy completely. The distribution of uranium fuel in aluminum-clad reactor fuel elements can be determined using x-ray radioscopy in a similar manner. Another requirement was to provide this determination within a short (1 or 2 minute) time frame.

*Lithium occurs in nature as a mixture of two isotopes, 7.5% ⁶Li and 92.5% ⁷Li; enrichment alters the ratio of these isotopes in the target alloy. Lithium-6, ⁶Li, and Li⁶ all refer to the same isotope.

THE NEUTRON RADIOSCOPY SYSTEM

The use of neutron radiation for this work is particularly favorable because enrichment of the Li-Al alloy with its ^{6}Li isotope gives the alloy a very high cross section for neutron removal (typically 940 barns) relative to that of the aluminum (0.9 barns)⁽⁴⁾ thereby providing excellent image contrast. Radioscopy refers to the technique of imaging hidden components of an object with radiation transmitted through the object and recorded in a non-permanent manner. In the radioscopy described in this report, the image is stored electronically and presented to the operator on a CRT screen. The Army has an interest in neutron imaging systems for aircraft examination and other non-destructive examination purposes which requires that the neutron source be mobile. This requirement has led the implementation of neutron radiography away from the use of nuclear reactor sources and towards the use of less encumbered, small californium-252 and accelerator sources. The radioscopy in these studies was accomplished primarily with a small accelerator source system which provides about 1/500 of the thermal neutron flux provided by reactor sources for radioscopy.^(5,6) The accelerator generates 14.3 MeV neutrons which are moderated in oil to thermal energies for radioscopy. It is shown in operation in Figure 2. The source and collimator system is mounted on a mobile frame, weighs 4900 pounds (2200 kg), and occupies a volume of approximately 15 ft x 5 ft x 4 ft (4.6 m x 1.5 m x 1.2 m). It was appropriate to utilize this unit for this work because it provides a model system for possible installation within a target fabrication plant.

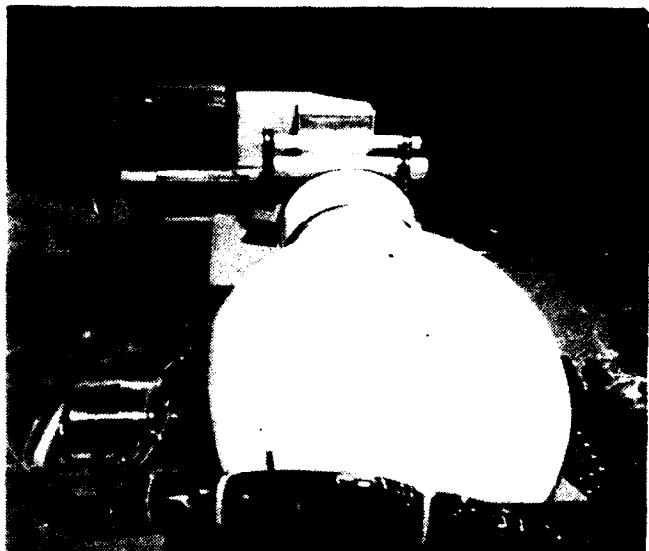


Fig. 2. View of the radiosscopic setup. The white sphere in the foreground houses the accelerator source and moderator. The collimated neutron beam from the source head illuminates the two tube sections set up horizontally in front of the 10in x 10in screen of the imaging system.

The electronic imaging system employed is of very high sensitivity, specifically designed to work with the low fluxes of small neutron source systems.⁽⁷⁾ In this imaging system, the neutrons are detected by a lithiumloaded phosphor whose light emission is detected with a cooled silicon intensified target tube from which the image is scanned out and placed in memory in digital form under control of a computer. Special hardware and software intervene at the scanning stage to provide a very low noise environment. Normally a series of scanned images is summed and then presented for viewing so that the minimum "exposure" time in these studies was about 3 seconds. Electronic imaging of this type has the advantage of allowing the operator to terminate the exposure when the image has built up sufficient contrast to provide a clear decision regarding the condition of the object under

TABLE I. TARGET TUBE CHARACTERISTICS

Tube No.	Diameter (in.)	^6Li Content (g/ft)	^6Li Density (mg/cm^2)	Approx. Imaging Time (sec.)
1	1.3	3.21	10.2	less than 3
2	3.6	4.09	4.67	less than 5
3	1.3	0.65	2.06	10
4	3.6	0.81	0.93	30
5	1.3	0.29	0.92	30
6	3.6	0.55	0.63	60
7	1.3	0.19	0.60	60
8	1.3	0.13	0.41	see text
9	1.3	0.10	0.32	see text

examination. Neutron activation of the object is kept at a minimum by this technique and by the inherently low flux of a small source.

RESULTS ATTAINED

A representative series of tubes examined is listed in Table I. They cover a range of practical interest with lithium-6 isotope contents from 0.1 g/ft to 4 g/ft. For comparison with radioscopic image densities, these concentrations have been expressed as an areal density in mg/cm^2 in column 4 of Table I. For tubes at the top of the concentration range, clear radioscopic images were presented for viewing in less than 5 seconds. It should be possible to view the lithium distribution in real time for these tubes. Images collected in less than 1/20th second and presented consecutively would allow viewing while the tube is rotated to ensure that the most extreme extent of lithium is located. Our image collection software does not allow for true real-time presentations, so we were unable to demonstrate this during our work.

Clear images from which core end determinations could be made were obtained within one minute of exposure time for all but those having the lowest

areal lithium-6 concentration, those noted as 0.10 and 0.13 g/ft. Thus for concentrations above 0.2 g/ft, small source neutron radiosity would appear to be a satisfactory nondestructive tool. The detection sensitivity seemed to drop markedly for the lowest lithium-6 concentrations, however.

In order to reduce exposure times to a minimum, the radiography system was operated with a low L/D ratio of 14/1, which was expected to provide sufficient resolution in the images for the purpose intended. A radiological determination made from an item having curved surfaces such as cylinders is often difficult because a sharp edge with a well defined contrast change is not available. A typical radioscopic image which shows three tube core ends is reproduced in Figure 3. The tube having the highest concentration of lithium-6 readily shows the location of the Li-Al alloy and graphically demonstrates its nonuniform distribution. Here one can use the whole image to make a determination of the extreme extent of the alloy. The tube on the left in Figure 3 contains a moderate amount of lithium-6 and the contrast over the center region of the tube does not provide a good measure of the core end. Here one relies on the view of the curved edges of the tube where the cylindrical shape places some

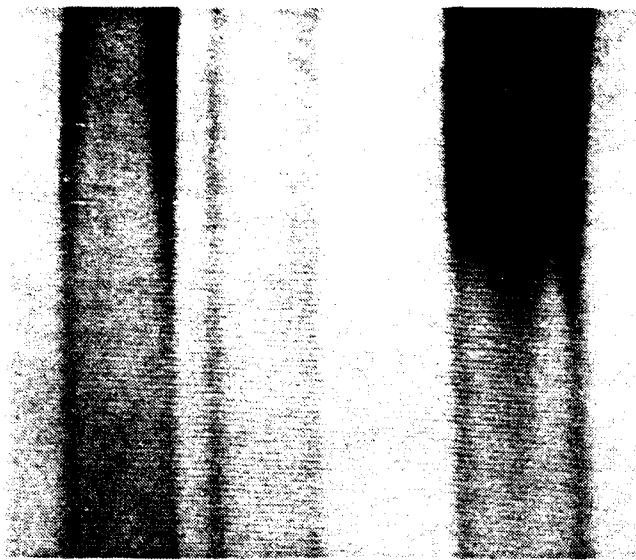


Fig. 3. A neutron radioscopic image of three small diameter target tubes in the region of the core ends. The tubes have average areal densities of Lithium-6, left to right, of 2.06, 0.32, and 10.2 mg/cm². This CRT image is reversed in radiographic density, black delineates an absorber. L/D is 14.1.

depth of lithium-6 in line with the radiation beam. For routine determinations, the tube would be rotated to assure that the extreme of the core end is being viewed. The center tube in Figure 3 contains so little lithium-6 that the low contrast and low resolution has lost even the curved edge image to the casual viewer. The ability to see the edge of any of the core ends is further hindered by the thinning of the alloy core to a shallow wedge shape as the end is approached. It is apparent that greater care with the radiological setup and the sacrifice of a longer image collection time may be needed to attain success at the lowest lithium-6 concentrations.

A neutron film radiograph of a low concentration tube, taken at an L/D ratio of 27.4/1 for improved resolution, Figure 4, makes the factors discussed above clear. Using the radiograph presented in Figure 4, the location of

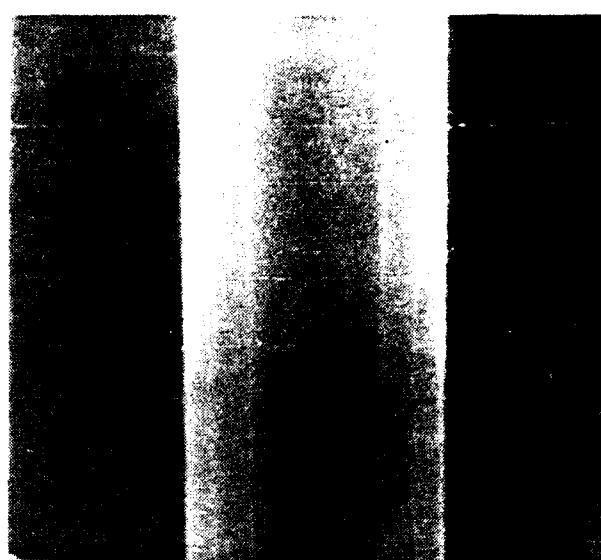


Fig. 4. A neutron radiograph (on x-ray film) of one of the large diameter target tubes with an areal density of Lithium-6 of 0.63 mg/cm². It illustrates the need for better resolution when dealing with very low lithium loadings. L/D is 27.4.

core end can be identified easily. Also visible is the wedge-shaped character of the alloy core near its end. This suggests the need for higher resolution or other image improvements to outline the core distribution at the lowest areal densities.

IMAGE PROCESSING

We have found that some form of image processing or enhancement is beneficial to making determinations of core end locations in tubes containing less than about 0.4 g/ft of lithium-6. The extent of the processing is probably best determined by the facilities available at the place where the determinations are made and by the difficulty in making an individual determination. Take the example of the 0.1 g/ft tube shown in the center of Figure 3. A trained viewer can see the general location of the lithium alloy core in this CRT screen view (at the top of the figure), but cannot determine its exact extent.

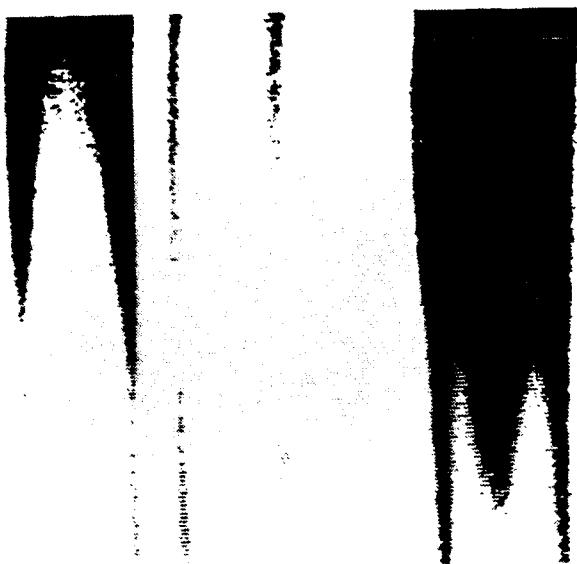


Fig. 5. A CRT screen view showing the result of applying a "masking" process to the radiosscopic image in Figure 3 to clarify the location of Li-Al alloy in the center tube.

As a first try, the following simple image enhancement procedure may be executed quickly. A determination is made of the maximum and minimum screen illuminance in the suspected core area. This is usually available as a profile

of brightness across the selected portion of the image or as maximum and minimum values of brightness within a selected rectangular area of the image. All values of brightness between the maximum and minimum are then set to "1" (white) in the computer memory and all other brightness values in the image are set to "0" (black). This is a common process sometimes called "masking". The result of applying this process to Figure 3 is shown in Figure 5. The low concentration center tube now shows the presence of alloy core much more clearly. This rather simple enhancement procedure may suffice in many cases. Here, the extent of the core is still questionable.

Adding additional processing steps eliminates any question of core extent. Figure 6(a) is a CRT image of the same tube shown at the center of Figure 3. The tube is now translated along its long axis so that only an all-aluminum

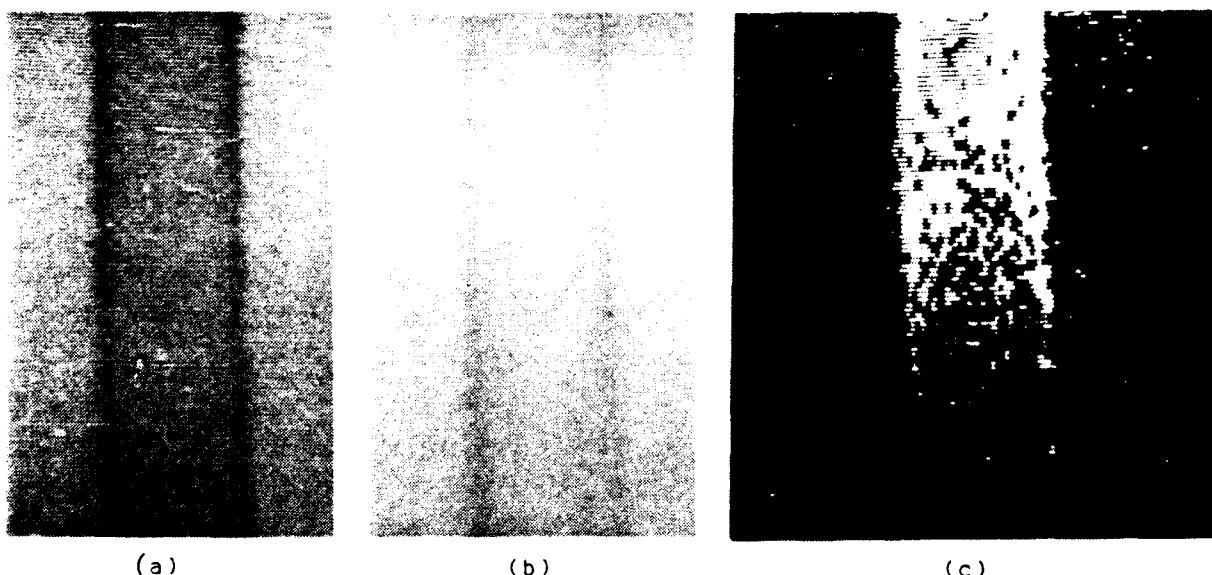


Fig. 6. (a) A neutron radiosopic image of the low lithium-6 content tube (0.32 mg/cm^2) shown in the center of Figure 3. The Li-Al alloy extent from the top of the tube is uncertain. (b) A neutron radiosopic image of an all-aluminum portion of the same tube. (c) The image resulting from applying a masking process to the pixel-by-pixel quotient of image (a) divided by image (b). The extent of the Li-Al alloy core is now quite certain.

portion of the tube is imaged, Figure 6(b). This image is now subtracted from or divided into that containing the alloy core, pixel by pixel, which results in an image of the core alone. The masking process can now be applied to the resultant image to provide stark contrast for the remaining significant illuminance levels, as shown in Figure 6(c). The full extent of the lithium core is now readily visible. This type of image processing eliminates the clutter in the background which makes it difficult for the human eye to isolate the image information of importance.

SUMMARY

The feasibility of using neutron radioscopy utilizing a small neutron source and electronic imaging to determine the location of Li-Al alloy core ends in target tubes fabricated for tritium production has been demonstrated. Accurate determinations appear to be possible by straightforward application of radioscopy within practical time constraints for target tubes containing concentrations of lithium-6 isotope above 0.2 g/ft of tube length. Below this concentration the usual trade-off between image resolution and exposure time must favor higher resolution in the images and require longer times for a determination to be made. The application of some image enhancement may also be traded off to obtain a shorter exposure time. In a particular application, the available software and its ease of application should determine the most suitable enhancement technique. It was demonstrated further that the required neutron radiology could be accomplished with a neutron source small enough that its installation within the tube

fabrication plant should be possible.

REFERENCES

- (1) K. H. Beckurts and K. Wirtz, Neutron Physics, Springer-Verlag, New York, 1964, p. 14.
- (2) S. R. Salaymeh and T. P. Varallo, Savannah River Laboratory, Technical Division internal reports, June-December, 1988.
- (3) Analysis Report, U. S. Army Materials Technology Laboratory, MT&E Branch, 1988.
- (4) D. I. Garber and R. R. Kinsey, Neutron Cross Sections, BNL 325, 3rd Ed, Vols. I & II, 1973.
- (5) J. J. Antal, W. E. Dance, S. F. Carollo and J. D. Moravec, "Experience with an On-Off Mobile Neutron Radiography System", in Neutron Radiography, J. P. Barton, G. Farney, J. Person and H. Rottger, Eds., D. Reidel Publishing Company, Dordrecht, Holland, 1987.
- (6) J. J. Antal and A. S. Marotta, "A Neutron Radiography system for Field Use", in Nondestructive Testing and Evaluation for Manufacture and Construction, H. Reis and W. J. McGonnagle, Eds., Hemisphere Publishers, 1989 (in press).
- (7) W. E. Dance and S. F. Carollo, "High Sensitivity Real Time Imaging System for Reactor or Non-Reactor Neutron Radiography", in Proceedings of the 2nd World Conference on Neutron Radiography, J. P. Barton, G. Farney, J. Person and H. Rottger, Eds., D. Reidel Publishing Company, Dordrecht, Holland, 1987.

DISTRIBUTION LIST

No. of Copies	To	No. of Copies	To
	Office of the Under Secretary of Defense for Research and Engineering, The Pentagon, Washington, DC 20301		Commander, U.S. Army Missile Command, Redstone Scientific Information Center, Redstone Arsenal, AL 35898-5241
1	ATTN: Mr. J. Persh	1	ATTN: AMSMI-RD-CS-R/Doc
1	Dr. L. Young	1	AMSMI-R, Dr. W. C. McCorkle
1	Mr. K. R. Foster		Commander, U.S. Army Aviation Systems Command, P.O. Box 209, St. Louis, MO 63120-1798
	Commander, U.S. Army Laboratory Command, 2800 Powder Mill Road, Adelphi, MD 20783-1145	1	ATTN: AMSAV-NS, Mr. M. L. Bauccio
2	ATTN: AMSLC-IM-TL	1	Technical Library
1	AMSLC-TD		Commander, U.S. Army Natick Research, Development and Engineering Center, Natick MA 01760
1	AMSLC-TD-A	1	ATTN: Technical Library
1	AMSLC-PA	1	Dr. R. Lewis
1	AMSLC-TP		Commander, U. S. Army Satellite Communications Agency, Fort Monmouth NJ 07703
1	AMSLC-CT	1	ATTN: Technical Document Center
	Commander, Defense Technical Information Center, Cameron Station, Building 5, 5010 Duke Street, Alexandria VA 22304-6145		Commander, U. S. Army Communications and Electronics Command, Fort Monmouth NJ 07703
2	ATTN: DTIC-FDAC	1	ATTN: AMSEL-TDD, Mr. Joseph T. Furia
1	National Technical Information Service, 5285 Port Royal Road, Springfield VA 22161		Director, Electronic Technology and Devices Laboratory, Fort Monmouth NJ 07703
	Director, Defense Advanced Research Projects Agency, 1400 Wilson Boulevard, Arlington VA 22209	1	ATTN: DELET-D, Dr. C. G. Thornton
1	ATTN: P. Parrish		Commander, U.S. Army Tank-Automotive Command, Warren, MI 48397-5000
	Department of the Army, Office of the Assistant Secretary of the Army (RDA), Washington DC 20310	1	ATTN: Dr. W. Bryzik
1	ATTN: Dr. G. Prather, Deputy for Science & Technology	1	Dr. Rose
1	Sr. J. R. Sculley, SARD	1	AMSTA-RKA
1	Lt. Col. Louis M. Jackson, Installations & Logistics	1	AMSTA-UL, Technical Library
	Headquarters, Dept. of the Army Deputy Chief of Staff, RD&A Washington DC 20310		Commander, U.S. Army Armament, Munitions and Chemical Command, Dover NJ 07801
1	ATTN: DAMA-ZE, Mr. G. M. Church	1	ATTN: Technical Library
	Commander, U. S. Army Research and Development Office Chief of Research and Development, Washington DC 20315	1	E. Barnes
1	ATTN: Physical and Engineering Sciences Division	1	G. Drucker
	Commander, Army Research Office, P. O. Box 12211, Research Triangle Park NC 27709-2211		Commander, U.S. Army Armament, Munitions and Chemical Command, Rock Island IL 61299
1	ATTN: Information Processing Office	1	ATTN: Technical Library
1	Dr. J. Hurt		Commander, Aberdeen Proving Ground MD 21005
1	Dr. A. Crowson	1	ATTN: AMDAR-CLB-PS, Mr. J. Vervier
1	Dr. R. Reebert		Director, U.S. Army Ballistic Research Laboratory, Aberdeen Proving Ground MD 21005
1	Dr. R. Shaw	1	ATTN: SLCBR-TSB (STINFO)
	Commander, U. S. Army Materiel Command, 5001 Eisenhower Ave, Alexandria VA 22333	1	SLCBR-RLT Dr. A. M. Dietrich
1	ATTN: AMCLD	1	SLCBR-BLF Dr. A. Miller
1	AMCOA, Mr. S. J. Lorber		Commander, U. S. Army Test and Evaluation Command, Aberdeen Proving Ground MD 21005
	Commander, U.S. Army Systems Analysis Activity, Aberdeen Proving Ground MD 2100	1	ATTN: AMSTE-ME
1	ATTN: AMXSY-MP, H. Cohen	1	AMSTE-TD
	Commander, U. S. Army Night Vision Electro-Optics Laboratory, Fort Belvoir VA 22060		Commander, U. S. Army Proving Grounds, Yuma AZ 85365-9103
1	ATTN: DELNV-S, Mr. P. Travesky	1	ATTN: STEYP-MLS-P, Mr. James Moravec
1	DELNV-L-D, Dr. R. Ruser		Commander, U.S. Army Material Command Science and Technology Center, Far East, APO San Francisco, CA 06328-5000
1	DELNV-D, Dr. L. Cameron	1	ATTN: AMXMI-J-OP, David Baker
	Commander, Harry Diamond Laboratories, 2800 Powder Mill Road, Adelphi MD 20783		Commander, U.S. Army Materiel Command Science and Technology Center - Europe, APO New York, NY 09079-4734
1	ATTN: Technical Information Office	1	ATTN: AMXMI-E-OP, Joe Crider
1	SLCHD-RAE		Commander, U.S. Army Foreign Science and Technology Center, 220 7th Street, N.E., Charlottesville, VA 22901-5396
	Director, U.S. Army Research and Technology Laboratories, Ames Research Center, Moffet Field CA 94035	3	ATTN: AIFRTC, Applied Technologies Branch, Gerald Schlesinger
1	ATTN: DAVDL-D, Dr. A. Carlson		
1	DAVDL-A-D, Dr. I. C. Slater, MS215-1, Aeromechanics Laboratory		

No. of Copies	To	No. of Copies	To
1	Commander, Dugway Proving Ground, Dugway UT 8022 ATTN: Technical Library	1	Commander, Naval Surface Weapons Center, White Oak X-Ray Laboratory 70-106, Silver Spring MD 20910 ATTN: Paul Wesley Brown, Jr.
1	U. S. Army Corps of Engineers Construction Engineering Research Laboratory, P. O. Box 4005, Champaign IL 61820 ATTN: Dr. Robert Quattrone	1	Commander, Naval Material Industrial Resources Office, Building 537-2, Philadelphia Naval Base, Philadelphia PA 19112 ATTN: Technical Director
1	Commander, U. S. Army Engineer Waterways Experiment Station, Vicksburg MS 39180 ATTN: Research Center Library Jack Lewis	1	Commander, Naval Air Station, North Island, San Diego CA 92135 ATTN: Code 610, Robert Mathers Code 610, E. K. Bonnes, Bldg. 5 Code 610, Ray Thompson, Jr.
1	Commander, U. S. Army Engineer School, Fort Belvoir VA 22060 ATTN: Library	1	Commander, Alameda Naval Air Station, Naval Air Rework Facility, Alameda CA 94501 ATTN: John Parsons
1	Commander, U. S. Army Belvoir R&D Center, Fort Belvoir VA 22060-5606 ATTN: STRBE-ZTS, Dr. K. H. Steinbach, Ch. Scientist AMDE-ZT, Technical Director	1	Commander, McClellan Air Force Base, Sacramento CA 95652, ATTN: SM-ALC/MANR Douglas Froom SM-ALC/MANR Wade Richards
1	Commander, Rock Island Arsenal, Rock Island IL 61299 ATTN: SAR1-EN AMXIB-MT	1	Commander, U.S. Air Force Wright Research & Development Center, Wright-Patterson Air Force Base, OH 45433-6523 ATTN: WRDC/MLLP Mr. D. Forney WRDC/MLBC Mr. Stanley Schulman WRDC/MLTM Mr. Lee Guiley
1	Director, Benet Weapons Laboratory, Watervliet NY 12189 ATTN: AMSMC-LCR-TL AMSMC-LCR-R	1	Commander, Air Force Armament Center, Elgin AFB FL 32542 ATTN: Technical Library
1	Commander, U.S. Army Aviation Systems Command, Aviation Research and Technology Activity, Aviation Applied Technology Directorate, Fort Eustis, VA 23604-5577 ATTN: SAVDL-E-MOS	1	Commander, White Sands Missile Range, Electronic Warfare Laboratory, DMEW ERADCOM, White sands NM 8002 ATTN: AMSEL-WLM-ME Mr. Thomas Reader
1	Project Manager, Munitions Production Base, Modernization and Expansion, Dover NJ 07801 ATTN: AMCPM-PBM-P	1	National Aeronautics and Space Administration, Scientific and Technical Information Facility, P. O. Box 8757, Balt/Wash International Airport MD 21240
1	Technical Director, Human Engineering Laboratories, Aberdeen Proving Ground MD 21005-5001 ATTN: SLCHE-D	1	National Aeronautics and Space Administration, Langley Research Center, Hampton VA 23665 ATTN: Mr. J. Buckley, MS 387 Dr. J. Heyman, MS 231
1	Commander, U.S. Army Aeromedical Research Laboratory, P.O. Box 577, Fort Rucker AL 36360 ATTN: Technical Library Dr. W. C. Chiou, Bio-Optics Div.	1	National Aeronautics and Space Administration, Marshall Space Flight Center, Huntsville AL 35812 ATTN: R. J. Schwinghammer, Dir. MAP Laboratory W. A. Wilson, Bldg. 612
1	Commander, Sharpe Army Depot, Lathrop CA 95331 ATTN: SDSSH-005, John Barnes, Bldg. 611	1	Department of Energy, Division of Transportation, 20 Massachusetts Ave, N.W., Washington DC 20545 ATTN: Dr. R. J. Gottschall, ER-131 GTN
1	Commander, U.S. Army Agency for Aviation Safety, Fort Rucker AL 36362 ATTN: Technical Library	1	National Institute of Standards and Technology, Gaithersburg MD 20899 ATTN: Dr. R. S. Carter, Ch. Reactor Radiation Center Dr. J. J. Rush Dr. Lyle Schwartz
1	Commander, USACDC Air Defense Agency, Fort Bliss TX 79916 ATTN: Technical Library	1	Argonne National Laboratory, Argonne IL 60439 ATTN: Dr. Alex De Volpi, RAS/Bldg 208
1	Commander, U.S. Army Missile Command, Redstone Arsenal AL 35898-5241 ATTN: AMSMI-RD-CS-R/Doc AMSMI-RLM	1	Argonne National Laboratory, P. O. Box 2528, Idaho Falls ID 83401 ATTN: Dr. Grant McClellan
1	Chief of Naval Research, Arlington VA 22217 ATTN: Code 471	1	Lawrence Livermore National Laboratory, P. O. Box 508, Livermore CA 94550 ATTN: Jerry Haskins, L-333
1	Naval Research Laboratory, Washington DC 20375 ATTN: Code 53R0 Code 63P4, Dr. G. R. Yoder	1	Los Alamos National Laboratory, P. O. Box 1663, Los alamos NM 87545 ATTN: Ron London Dr. D. H. Janney
1	Headquarters, Naval Air Systems Command, Washington DC 20360 ATTN: Code 5203	1	Oak Ridge National Laboratory, P. O. Box 2008, Oak Ridge TN 37831-6384 ATTN: Mr. John E. Bigelow Mr. Dennis E. Benker
1	Headquarters, Naval Sea Systems Command, 1941 Jefferson Davis Highway, Arlington VA 22376 ATTN: Code 035	1	Oak Ridge National Laboratory, P. O. Box 2008, Oak Ridge TN 37831-6228 ATTN: Dr. Colin D. West Ms. Sherry M. Gibson
1	Headquarters, Naval Electronics Systems Command, Washington DC 20360 ATTN: Code 504		

No. of Copies	To	No. of Copies	To
	Sandia National Laboratory, P. O. Box 5800, Albuquerque NM 87185		Atomic Energy of Canada Limited, Chalk River Nuclear Laboratories, Ontario K0J 1J0, Canada
1	ATTN: Robert W. Mottern	1	ATTN: Dr. Alan M. Ross
1	Battelle Pacific Northwest Laboratory, Richland WA 99353		AVCO Corporation, Applied Technology Division, Lowell Industrial Park, Lowell MA 01887
1	ATTN: Mr. A. Birks, NDT Section	1	ATTN: Dr. T. Vasilos
	Bettis Atomic Power Laboratory, P. O. Box 79, West Mifflin PA 15122		Boeing Aerospace Company, 11029 Southeast 291, Auburn MA
1	ATTN: Dr. Stanley Glickstein	1	ATTN: W. E. Strobelt
	EG & G Mound Laboratory, P. O. Box 32, Miamisburg OH 45342		Corning Glass Works, Research and Development Division, Corning NY 14830
1	ATTN: Mr. James D. Hastings	1	ATTN: Dr. W. R. Prindle
1	Mr. E. Dane Harvey		The Charles Stark Draper Laboratory, 68 Albany Street, Cambridge MA 02139
	Westinghouse Savannah River Laboratory, P.O. Box 616, Aiken SC 29800-0001	1	ATTN: Adrian Stecyk
1	ATTN: Dr. S. Salaymeh, Bldg. 773 A		General Atomic company, TRIGA Reactors Facility, P. O. Box 8168, San Diego CA 92138
	Georgia Institute of Technology, EES, Atlanta GA 30332	1	ATTN: Dr. William L. Whittemore
1	ATTN: Mr. J. D. Walton		General Dynamics, Convair Aerospace Division, P. O. Box 748, Fort Worth TX 76101
	Johns Hopkins Applied Physics Laboratory, Johns Hopkins Road, Laurel MD 20707	1	ATTN: Mfg. Engineering Technical Library
1	ATTN: Jim Kouroupis, Rm 6-387		Hahn-Meitner-Institut fur Kernforschung, Glienicker Strasse 100, 1000 Berlin 39
	The Johns Hopkins University, Department of Materials Science and Engineering, Baltimore MD 28218	1	ATTN: Dr. Carl-Otto Fischer, Reactor Div.
1	ATTN: Dr. R. E. Green, Jr		Industrial Quality Inc., P. O. Box 2519, 19634 Club House Road, Gaithersburg MD 20879
	Lehigh University, Materials Research Center, Bethlehem PA 18015	1	ATTN: Mr. Harold Berger
1	ATTN: Dr. D. M. Smyth		Industrienlagen-Betriebsgesellschaft mbh, 8012 Ottobrunn, b. Munchen, West Germany
	Massachusetts Institute of Technology, Department of Nuclear Engineering, Cambridge MA 02139	1	ATTN: Dr. Gerd K. F. Strassner
1	ATTN: Prof. E. W. McFarland	1	Ing. Horst Zocher
1	Prof. R. C. Lanza		IRT Corporation, 3030 Callan Road, San Diego CA 92121
	Pennsylvania State University, Materials Science Department, University Park PA 16802	1	ATTN: Jeff Stokes
1	ATTN: Prof. R. Roy		Lockheed-Georgia Company, Lockheed Georgia Nuclear Laboratory, Dawsonville GA
1	Prof. E. Newham	1	ATTN: Jack K Grant
1	Mr. C. O. Ruud		Lockheed Missiles and Space Company, 815 E. Middlefield Road, Mountain View CA 94043
	Pennsylvania State University, 231 Sackett Building, University Park PA 16802	1	ATTN: Paul R. Zydner, 0/93-60 B/533
1	ATTN: Prof. Samuel Levine	1	ATTN: R. A. Buchanan, 0/52-36 B/533
	Rensselaer Polytechnic Institute, Department of Materials Engineering, Troy NY 12181	1	Clifford Bueno, 0/93-60 B/533
1	ATTN: R. J. Diefendorf		LTV Missiles and Electronics Group, Missiles Division, P.O. Box 650003, Dallas TX 75265-0003
	Royal Military College, Dept. of Chemistry and Chemical Engineering, Kingston, Ontario, Canada K7K 5L0	2	ATTN: Dr. William E. Dance
1	ATTN: Dr. Les G. Bennett		3M Company, New Products Department, 3M Center, St. Paul MN 55144
	Syracuse University, 304 Administration Building, Syracuse NY 13210	1	ATTN: R. E. Richards, 219-01-01
1	ATTN: Dr. V. Weiss		Martin-Marietta Laboratories, 1450 South Rolling Road, Baltimore MD 21227
	University of Florida, Dept. of Materials Science and Engineering, Gainesville FL 32611	1	ATTN: Dr. J. Venables
1	ATTN: Dr. L. Hench		MF Physics Corporation, 4720 Forge Road, Suite #112, Colorado Springs CO 80907
	University of Lowell, Radiation Laboratory, University Avenue, Lowell MA 01854	1	ATTN: Dr. Manfred Fry
1	ATTN: Mr. Tom Wallace		Northrup Corporation, Electronics Division, 100 Morse Street, Norwood MA 02062
	University of Michigan, Highway Safety Research Institute, Huron Parkway & Baxter Road, Ann Arbor MI 48109	1	ATTN: J. David Ledoux
1	ATTN: Dr. Max Bender		Reinhart Associates Inc, P. O. Box 9802, Suite 173, Austin TX 78766
	University of Michigan, Ford Nuclear Reactor, 2301 Bonisteel Blvd, North Campus, Ann Arbor MI 48109	1	ATTN: Dr. Ronald Larson
1	ATTN: Dr. John B. Jones		Science Applications International Corporation, 10401 Roselle Street, San Diego CA 92121
	University of Virginia, Nuclear Reactor Facility, Charlottesville VA 22901	1	ATTN: Dr. Victor Orphan
1	ATTN: Dr. J. S. Brenizer, Jr		United Technologies Pratt & Whitney, 400 Main Street, East Hartford CT 06108
	Aerospace Corporation, Materials Science Laboratory, 2350 East El Segundo Blvd, El Segundo CA 90245	1	ATTN: Paul A. Chouinard
1	ATTN: Dr. L. R. McCreight		Director, U. S. Army Materials Technology Laboratory, Watertown, MA 02172-0001
	Aerotest Operations Inc, 3455 Fosteria Way, San Ramon CA 94583	2	ATTN: SLCMT-TML
1	ATTN: Richard L. Mewacheck	4	Authors

J. S. Army Materials Technology Laboratory,
Watertown, Massachusetts 02172-0001
THE APPLICATION OF NEUTRON RADIOSCOPY
TO LITHIUM-ALUMINUM ALLOY TARGET ELEMENTS -
John J. Antal, Alfred S. Marotta, Saleem R.

AD _____
UNCLASSIFIED
UNLIMITED DISTRIBUTION
Key Words
Li-Al alloys
Dilute alloys

Technical Report MIL TR 90-10, April 1950, 9 pp - illus-table

We have shown that neutron radiography is very useful in locating the position of a Li-Al alloy core enriched in Lithium-6 in tubular aluminum target elements. The alloy core is displaced during a forming process and its location must be determined before processing can be completed. The Army's low-flux mobile neutron radiography system was employed in these studies as a model system for possible on-line, in-plant use. A series of core end sections of target tubes containing from 0.1 to 1.6 grams of Lithium-6 per foot of length were examined radioscopically with thermal neutrons. The system was able to determine the extent of lithium alloy core from concentrations down to about 0.2 grams of Lithium-6 per foot within one minute of data collection time. A marked loss of sensitivity below this level could be recovered by providing higher geometrical resolution in the images obtained or by using image enhancement techniques. Film radiography was used to verify the accuracy of radioscopic determinations at the lowest lithium concentrations.

U.S. Army Materials Technology Laboratory,
Watertown, Massachusetts 02112-0001
THE APPLICATION OF NEUTRON RADIOSCOPY
TO LITHIUM-ALUMINUM ALLOY TARGET ELEMENTS -
John J. Antal, Alfred S. Marotta, Saleem R.

U.S. Army Materials Technology Laboratory,
Watertown, Massachusetts 02172-0001
THE APPLICATION OF NEUTRON RADIOSCOPY
TO LITHIUM-ALUMINUM ALLOY TARGET ELEMENTS -
John J. Antal, Alfred S. Marotta, Saleem R.
Salaymeh, and Thomas P. Varallo
Technical Report MTI TR 00 19 April 1969

We have shown that neutron radioscopy is very useful in Al-Al alloy core enriched in Lithium-6 in tubular alloy core is displaced during a forming process as determined before processing can be completed. The radioscopy system was employed in these studies as a means in plant use. A series of core end sections of total 4.6 grams of Lithium-6 per foot of length were taken. The system was able to determine the exact highest concentrations down to about 0.2 grains/minute of data collection time. A marked loss of information can be recovered by providing higher geometrical resolution using image enhancement techniques. Film radiography accuracy of radioscopic determinations at the lower

AD UNCLASSIFIED
UNLIMITED DISTRIBUTION
Key Words

AD UNCLASSIFIED
UNLIMITED DISTRIBUTION
Key Words
Li-Al alloys

Radiography
Neutron radiography
radiating the position of a
target elements. The
relocation must be redeter-
mined by mobile neutron radi-
ography for possible on-line
s containing from 0.1 to
radioisotopically with therm-
ium alloy core from
per foot within
this level cou-
ntrate images obtained or
used to verify the
concentrations.

AD _____
UNCLASSIFIED
UNLIMITED DISTRIBUTION
Key Words
Li-Al alloys
Boron
I.S. Army Materials Technology Laboratory,
Watertown, Massachusetts 02172-0001
THE APPLICATION OF NEUTRON RADIOSCOPY
TO LITHIUM-ALUMINUM ALLOY TARGET ELEMENTS -
John J. Antal, Alfred S. Marotta, Saleem R.
Salameh, and Thomas P. Varallo
Technical Report MTI TR 90-18, April 1990, 9 pp.

AD UNCLASSIFIED
UNLIMITED DISTRIBUTION

AD _____
UNCLASSIFIED
UNLIMITED DISTRIBUTION
Key Words
Li-Al alloys
oxidation
Technology Report MTI TR 90-18 April 1990 9 00 2

U.S. Army Materials Technology Laboratory,
Watertown, Massachusetts 02172-0001
THE APPLICATION OF NEUTRON RADIOSCOPY
TO LITHIUM-ALUMINUM ALLOY TARGET ELEMENTS -
John J. Anta, Alfred S. Marotta, Saleem R.
Salaymeh, and Thomas P. Varallo

AD _____
UNCLASSIFIED
UNLIMITED DISTRIBUTION
Key Words
Li-Al alloys
oxidation

11-illust-table

We have shown that neutron radiosity is very useful in locating the position of a Li-Al alloy core enriched in Lithium-6 in tubular aluminum target elements. The alloy core is displaced during a forming process and its location must be determined before processing can be completed. The Army's low-flux mobile neutron radiosity system was employed in these studies as a model system for possible on-line, in-plant use. A series of core end sections of target tubes containing from 0.1 to .6 grams of Lithium-6 per foot of length were examined radioscopically with thermal neutrons. The system was able to determine the extent of lithium alloy core from the highest concentrations down to about 0.2 grams of Lithium-6 per foot within one minute of data collection time. A marked loss of sensitivity below this level could be recovered by providing higher geometrical resolution in the images obtained or by using image enhancement techniques. Film radiography was used to verify the accuracy of radiosopic determinations at the lowest lithium concentrations.

AD UNCLASSIFIED
UNLIMITED DISTRIBUTION
Key Words

AD UNCLASSIFIED
UNLIMITED DISTRIBUTION
Key Words
Li-Al alloys

Radiography
Neutron radiography
radiating the position of a
target elements. The
relocation must be redeter-
mined by mobile neutron radi-
ography for possible on-line
s containing from 0.1 to
radioisotopically with therm-
ium alloy core from
per foot within
this level cou-
ntrate images obtained or
used to verify the
concentrations.